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TABLES OF THERMODYNAMIC PROPERTIES AND CALCULATIONS FOR DETERMINING EQUILIBRIUM COMPOSITION AND FLAME TEMPERATURE

REECE G. BELK, JR.

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TABLES OF THERMODYNAMIC PROPERTIES AND CALCULATIONS FOR DETERMINING EQUILIBRIUM COMPOSITION AND FLAME TEMPERATURE

* * * * *

Reece G. Belk, Jr.

TABLES OF THERMODYNAMIC PROPERTIES AND CALCULATIONS FOR DETERMINING EQUILIBRIUM COMPOSITION AND FLAME TEMPERATURE

by

Reece G. Belk, Jr.

Lieutenant, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

IN

ENGINEERING

United States Naval Postgraduate School
Monterey, California

1959

Thesis

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Reece G. Belk, Jr.

This work is accepted as fulfilling
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ABSTRACT

An iteration program is described for the determination of equilibrium composition and flame temperature of high energy fuels (HEF) and other chemical reactions.

Tables of thermodynamic functions and equilibrium constants needed for the calculations were prepared for sixteen (16) elements and compounds. Based on the ideal gas relationship, the method of computing values for the tables is shown. The CRC 102A digital computer was programmed to compute the values of thermodynamic functions and equilibrium constants presented in the tables; thereby providing a reasonably consistent set of data.

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TABLE OF CONTENTS

Section	Title	Page
1.	Introduction	1
2.	Procedure and Discussion	3
3.	Bibliography	12
4.	Symbols used in Tables	A-1
5.	Table I Formula Mass and Enthalpy of Formation at Absolute Zero Temperature	A-2
6.	Table II Argon (A)	A-3
7.	Table III Boron (B)	A-6
8.	Table IV Boron Oxide (BO)	A-9
9.	Table V Boron Trioxide (B_2 O_3)	A-12
10.	Table VI Carbon C	A-15
11.	Table VII Carbon Monoxide (CO)	A-18
12.	Table VIII Carbon Dioxide (CO_2)	A-21
13.	Table IX Atomic Hydrogen (H)	A-24
14.	Table X Molecular Hydrogen (H_2)	A-27
15.	Table XI Water Vapor (H_2O)	A-30
16.	Table XII Atomic Nitrogen (N)	A-33
17.	Table XIII Molecular Nitrogen (N_2)	A-36
18.	Table XIV Nitric Oxide (NO)	A-39
19.	Table XV Atomic Oxygen (O)	A-42
20.	Table XVI Molecular Oxygen (O_2)	A-45
21.	Table XVII Hydroxyl (OH)	A-48
22.	Table XVIII Equilibrium Constants	A-51
23.	Table XIX Equilibrium Constants	A-54
24.	Table XX Equilibrium Constants	A-57
25.	Table XXI Equilibrium Constants	A-60

1. Introduction.

The high energy fuels in present use and undergoing experimentation produce high temperatures upon combustion. On the assumption that chemical equilibrium exists among the products of combustion, it is possible to calculate the composition and the flame temperature, thereby predicting the theoretical performance of a propulsion system. For a system containing N products of reaction the simultaneous solution of at least N+1 equations is necessary. These may involve (1) mass balance, (2) dissociation and (3) energy and entropy balance. For nominal products of complete combustion of stoichiometric quantities the solution is complex, but at high temperatures, as dissociation occurs and the number of products of combustion increases, the calculations become increasingly difficult.

Since equilibrium composition and reaction temperature are interdependent, a series of successive approximations must be made beginning with a trial temperature. A number of methods for solving these equations have been proposed, Ref. (1), (8), (9), using trial and error, matrices, or other convergent approximations. Hand solutions are laborious, so it was proposed to program the solution on the Computer Research Corporation 102-A digital computer at the United States Naval Postgraduate School, Monterey, California. This project was completed during fall 1958 and spring 1959 in partial fulfillment of the requirements for the degree of Master of Sciences. The problem was based on the constant pressure combustion of a boron fuel containing carbon, hydrogen and boron (C,H,B) at atmospheric pressure using air as oxidizer and including up to 16 products of combustion. The program is also adaptable to use with other fuels, explosives or any chemical reaction that involves the elements Carbon, Hydrogen, Boron, Oxygen,

Nitrogen, and Argon.

Tables containing a consistent set of thermodynamic functions are a primary necessity when calculating equilibrium composition and flame temperature. For the elements and compounds included in this problem no such tables could be found in a single source nor in a readily useable form. Hence a large portion of the effort in this project was devoted to compilation of data and calculation of the thermodynamic functions given in Tables I - XXI. The sensible enthalpy, i.e. enthalpy based on the value at absolute zero temperature ($H^\circ - H_0^\circ$); the total entropy S°; and the change in free energy of formation ΔF_f°, containing enthalpy of formation at absolute zero, were tabulated for the temperature range 100° to 9900°R, Tables II - XVII. Equilibrium constants were calculated for the 11 reactions shown and these values tabulated over the temperature range 2000°R to 9900°R, Tables XVIII - XXI. All calculations were based on the ideal gas relationship. Values of specific heat at constant pressure C_p° may be easily obtained as first differences in enthalpy.

2. Procedure and Discussion

As a representative high energy fuel (HEF) containing carbon C, hydrogen H, and boron B: triethyl - diborane was chosen for use in the calculations. When burned with air containing twenty-one percent oxygen (21% O_2), seventy-eight percent nitrogen (78% N_2) and one percent argon (1% A). a number of compounds could be produced. Including products of dissociation, 16 elements and compounds, Table I, were chosen to work with. Based on methods in Refs. (1), (2) and (3), combinations of these products of combustion produced 11 possible equilibrium reactions, with some repetition shown by the water-gas reaction.

A readily available source of tabulated thermodynamic functions did not exist so it was decided that a reasonably consistent set of tables of data would be produced. Formula mass in Table I represents the latest values from the International Standards adopted in 1956. The enthalpy of formation at absolute zero temperature $(H^\circ_f)_\circ$, Table I, was taken from Refs. (4) and (6). A program was written for the CRC -102A digital computer such that basic values of thermodynamic properties could be stored in the computer memory and these used to compute the properties at intermediate temperatures. The enthalpy function was computed for a series of small temperature increments by the following formula from Ref. (1):

$$H = H_b + \bar{C}_p \, (T-T_b)$$

where the subscript b refers to a value at an arbitrarily selected basic temperature near the temperature of concern. Since enthalpy was based on the value at absolute zero temperature, the tabulated function is a "sensible enthalpy" and is a standard value at any given temperature minus the standard value at absolute zero, $H^\circ - H^\circ_\circ$.

The entropy was computed in much the same manner by the formula, Ref (1)

$$S = S_b + C_p \ln \frac{T}{T_b}$$

but since the entropy at absolute zero is equal to zero, the tabulated values become the standard value of total entropy S°, at any given temperature. As will be shown later in the flame temperature calculations, the fact that entropy equals zero at absolute zero makes this a good reference temperature to use during these calculations.

Basic values for Tables II - XVII were found in various dimensionless and dimensional forms in Refs. (4) - (9) which represented the most consistent sources available. In the computer these values were all converted to the English Standard of Engineering units (BTU/#mol) and all computations made and results presented in these units.

Enthalpy H, entropy S, and specific heat at constant pressure C_p for A, CO, CO_2, H, H_2, N, N_2, O and O_2 were taken from Refs. (4) and (5): for B, BO, B_2O_3, NO and OH from Ref. (6): and C (β graphite) from Ref. (7). Basic values were taken from the references at temperatures of 100°K, 298.16°K, 400°K, 500°K, 700°K, 1000°K, 1200°K, 1500°K, 2000°K, 2500°K, 3000°K, 3500°K, 4000°K, 4500°K and 5000°K. Smaller increments were chosen in the low temperature range because that is the region in which C_p changes more rapidly. A graphical extrapolation was made for Carbon to obtain basic values at 4500°K and 5000°K.

The specific heat C_p may be obtained by taking the first difference in enthalpies, i.e. for CO, Table VII:

$$H = H_{5500°R} - H_{5400°R} = C_p \Delta T$$

$$= (44,834 - 43,944) \text{ BTU/\#mol} = C_p \ (5500-5400)$$

$$C_p = \frac{891}{100} \frac{\text{BTU/\#mol}}{°R} = 8.91 \text{ BTU/(\#mol °R)}$$

The change in free energy of formation was calculated on the basis of formation from the elements and includes the enthalpy of formation at absolute zero temperature, Table I, hence tabulated values are standard values (ΔF_f°) for any given temperature. From Chapters 7 and 12 Ref. (1)

$$F_f = H - TS$$

$$\Delta F_f = \Delta H - \Delta (TS)$$

but since calculations were made on the basis of enthalpy and entropy functions at a single temperature, the term on the right of the equation becomes $T\Delta S$ and

$$\Delta F_f^\circ = \Delta H^\circ - T\Delta S^\circ$$

The function ΔF is the Gibbs' function or Gibbs' free energy, named after Willard Gibbs who first established this useful relationship. As an illustration; for the formation of atomic nitrogen from the free elemental molecular nitrogen

$$1/2\ N_2 = N$$

$$\Delta F_f^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta F_f^\circ = (H_N^\circ - 1/2\ H_{N_2}^\circ) + (H_f^\circ)_N - T(S_N^\circ - 1/2\ S_{N_2}^\circ)$$

Tabulated values of enthalpy, entropy, and change in free energy of formation are presented in Tables II - XVII.

The equilibrium reactions in Tables XVIII - XXI were formulated and equilibrium constants calculated on the basis of methods found in Refs. (1), (2) and (3). An important use of the Gibbs' free energy function became apparent in these calculations.

$$\Delta F_f^\circ = - RT \ln K_p$$

which states that when reactants in their standard states are changed to

products in their standard states there is a change in free energy equal to -RT times the natural logarithm of the equilibrium constant, Ref. (2). Then

$$\text{LN } K_p = -\frac{\Delta F_f^\circ}{RT} = \frac{-(\Delta H^\circ - T\Delta S^\circ)}{RT}$$

$$K_p = e^{-\left(\frac{\Delta H^\circ - T\Delta S^\circ}{RT}\right)}$$

for convenience in practical problems, the actual values of equilibrium constants were tabulated rather than a logarithm function. This limited tabulation in the low temperature range, but, with the free energy functions and the above formula, the equilibrium constant may be easily determined for any temperature.

Values in Tables II - XXI were computed on the digital computer and punched on IBM cards which were subsequently used in an IBM-402 Accounting Machine to print the tabular format.

With reasonably consistent values of the thermodynamic functions, the problem of equilibrium composition and flame temperature was attacked. Since these two parameters are interdependent, a trial temperature must be chosen and the composition determined; then a check for energy, entropy balance must be made and if the temperature was not correct a new trial value must be assumed. This procedure must be continued until the correct temperature, hence proper composition, is found.

For the 16 products of combustion, simultaneous solution of 17 equations is necessary. An iterative scheme of solution is used on the digital computer and this is best shown by an illustrative example. First choose a trial temperature, 5400°R, and having values of K_p, Tables XVIII - XXI, the interrelation between combustion products and reactants is established and equilibrium components may be determined. Burn the fuel completely with

stoichiometric quantity of air as oxidizer to determine the amounts of nominal (major) products. With triethyl-diborane the following reaction occurs

$$B_2H_3(C_2H_5)_3 + 12\ O_2 + (12)\ \frac{78}{21}\ N_2 + (12)\ \frac{1}{21}\ A = 6\ CO_2 + 9\ H_2O$$

$$+ B_2O_3 + 44.6\ N_2 + 0.571\ A$$

Now since complete burning rarely occurs in an engineering application without an excess of oxygen, include CO, H_2 and O_2 among the nominal products. The reaction then takes the form

$$B_2H_3(C_2H_5)_3 + 12\ O_2 + (12)\ \frac{78}{21}\ N_2 + (12)\ \frac{1}{21}\ A = a\ CO_2 + b\ H_2O$$

$$+ c\ B_2O_3 + d\ N_2 + e\ A + f\ CO + g\ H_2 + h\ O_2$$

where the letters a-h represent the unknown molar amounts. By a material balance equations may be written to equal the number of elements involved.

a	CO_2	Carbon (C)	$a + f = 6$
b	H_2O	Hydrogen (H)	$2b + 2g = 18$
c	B_2O_3	Boron (B)	$2c = 2$
d	N_2	Nitrogen (N)	$2d = 44.6$
e	A	Argon (A)	$e = 0.571$
f	CO		
g	H_2		
h	O_2	Oxygen (O)	$2a + b + 3c + f + 2h = 24$

Since only six (6) equations exist for these eight (8) unknowns one must resort to equilibrium equations for solution of the other two. To solve

for f choose the following equilibrium reaction from Table XVIII

$$CO_2 \rightleftharpoons CO + 1/2\ O_2$$

then by partial pressure, p, notation

$$K_p = \frac{P_{CO} + (P_{O_2})^{1/2}}{P_{CO_2}}$$

The partial pressure of a gas may be represented by the mole fraction times the total pressure. The unknown number of moles of carbon monoxide has been assigned the value f; let, sigma, Σ, equal the total number of moles of combustion products, then the mole fraction of CO is f/Σ. With the value of K_p at 5400°R from Table XVIII the above equation becomes

$$K_p = 0.32898 = \frac{f/\Sigma\ P\,(h/\Sigma\ P)^{1/2}}{a/\Sigma\ P}$$

$$0.32898 = \frac{f\,(h/\Sigma\ P)^{1/2}}{a}$$

From the carbon (C) material balance, a = 6 - f and

$$0.329 = \frac{f\,(h/\Sigma\ P)^{1/2}}{6 - f}$$

$$f = \frac{6\,(0.329)}{(h/\Sigma\ P)^{1/2} + 0.329} = \frac{1.974}{(h/\Sigma\ P)^{1/2} + 0.329}$$

where P is the total pressure in atmospheres. Solution for g, the moles of H_2, is completed in a similar manner. Then for each new product of combustion a new equilibrium equation must be solved. This points out

the need for values of equilibrium constants at various temperatures.

It should be noted that the solution for f contains the unknown h, for the number of moles of unburned oxygen; this will also occur in the solution for g. Since simultaneous solution of this large number of equations is difficult these are best solved by an iterative process. A trial value of h is chosen; solution for the other unknowns is made on the basis of this trial, then by the summation shown for the oxygen balance the trial value is checked. Considerable assistance is gained by making a table to show the operations involved, (see Iteration Table page 10).

The values of K_p predict negligible amounts of Boron and solid Carbon for this example. For products of dissociation involving other minor components, assign the following unknowns.

$$j = OH,\ k = H,\ l = O,\ m = N,\ n = NO,\ q = BO.$$

For the first iteration, only major products are considered to exist hence all minor products will be zero. The role played by pressure is indicated in the Iteration Table, but for convenience was taken as one (1) atmosphere.

At the end of the first iteration the value of h is determined and compared with the trial value. The discrepancy in h is taken as the calculated value minus the trial value. For the second trial value of oxygen divide the discrepancy by two (2) and add this to the first trial value of h. Now, however, all minor products of combustion should be included.

After the second iteration extrapolate (or interpolate) the discrepancy to zero to aid in the estimate of a trial value of h for the third iteration. The third trial should then give a reasonable answer provided no errors in arithmetic were made. Once programmed, this sort of iterative

ITERATION TABLE

h = trial O_2	2.50	2.46	2.50
$\Sigma = 38.87+h+j+k+l+m+n+q$	41.37	41.33	46.704
$(h/\Sigma P)^{1/2}$	.246	.244	.231
$f = \frac{1.974}{(h/\Sigma P)^{1/2}+ 0.329}$	3.440	3.450	3.530
$a = 6 - f$	2.560	2.550	2.470
$g = \frac{9}{21.96(h/\Sigma P)^{1/2}+ 1}$	1.410	1.420	1.484
$b = 9 - g - j - k$	7.590	7.580	4.336
$c = 1 + q$	1.000	1.000	1.000
$d = 22.3 - m - n$	22.330	23.300	21.337
$e = 0.571$ (const.)	0.571	0.571	0.571
$(g/\Sigma P)^{1/2}$		0.185	0.178
$j = \frac{0.0476\ b}{(g/\Sigma P)^{1/2}}$	0	1.960	1.160
$k = \Sigma/P\ (0.0248)\ (g/\Sigma P)^{1/2}$	0	1.200	1.310
$l = \Sigma/P\ (0.0144)\ (h/\Sigma P)^{1/2}$	0	1.210	1.300
$m = \Sigma/P\ (0.00137)\ (d/\Sigma P)^{1/2}$	0	0.043	0.043
$n = 0.1216\ d^{1/2}\ h^{1/2}$	0	0.920	0.890
$q = \Sigma/P\ (0.000089)\ \frac{(c/\Sigma P)^{1/2}}{(h/\Sigma P)^{1/4}}$	0	0.001	0.001
$h = 12 - (\frac{2a+b+3c+f+j+l+n+q}{2})$	2.42	0.39	2.43
Discrepancy in h = calculated - trial	-0.08	-2.07	-0.07

process is quickly and accurately completed on a digital computer.

Once the composition in number of moles of each product of combustion has been determined, the trial temperature must be checked. This is accomplished by an energy, entropy balance. If the temperature is incorrect a new value must be chosen and a new composition determined. It is advisable to choose the second temperature value such that it will be on the opposite side of the true value from the first trial. Then a more accurate estimate may be made and the theoretical flame temperature determined.

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TABLES OF

THERMODYNAMIC PROPERTIES AND EQUILIBRIUM CONSTANTS

Symbols

F	Gibbs' free energy of formation, BTU/#Mol
H	Total heat content, Enthalpy, BTU/#Mol
H_f	Enthalpy of formation, BTU/#Mol
K_p	Equilibrium constant, Dimensionless
M	Formula mass, #/#Mol
R	Gas constant, 1.9872 BTU/(#Mol °R)
S	Entropy, BTU/(#Mol °R)
T	Absolute temperature, °R
°	Superscript, denotes standard value at given temperature, i.e., H° is standard enthalpy
$_o$	Subscript, denotes temperature, i.e., H°_o is standard enthalpy at 0°R

TABLE I

FORMULA MASS AND ENTHALPY OF FORMATION

AT ABSOLUTE ZERO TEMPERATURE

Element or Compound	M	$(H_f^\circ)_\circ$
A	39.944	0
B	10.820	0
BO	26.820	- 10,800
B_2O_3	69.640	- 543,600
C	12.011	0
CO	28.011	- 48,963
CO_2	44.011	- 169,143
H	1.008	92,916
H_2	2.016	0
H_2O (g)	18.016	- 102,793
N	14.008	153,216
N_2	28.016	0
NO	30.008	38,659
O	16.000	105,455
O_2	32.000	0
OH	17.008	18,000

TABLE II

ARGON (A)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
100	000496	028.6374	0
150	000744	030.6517	0
200	000992	032.0809	0
250	001241	033.1895	0
300	001487	034.0925	0
350	001735	034.8583	0
400	001983	035.5217	0
450	002232	036.1068	0
500	002480	036.6303	0
537	002664	036.9849	0
600	002977	037.5360	0
700	003475	038.3048	0
800	003972	038.9681	0
900	004468	039.5532	0
1000	004965	040.0766	0
1100	005460	040.5501	0
1200	005957	040.9824	0
1300	006454	041.3801	0
1400	006951	041.7482	0
1500	007447	042.0910	0
1600	007942	042.4117	0
1700	008439	042.7128	0
1800	008936	042.9968	0
1900	009433	043.2654	0
2000	009928	043.5202	0
2100	010425	043.7626	0
2200	010922	043.9937	0
2300	011419	044.2146	0
2400	011916	044.4260	0
2500	012411	044.6287	0
2600	012907	044.8235	0
2700	013404	045.0110	0
2800	013901	045.1917	0
2900	014398	045.3660	0
3000	014895	045.5345	0

TABLE II

ARGON (A)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
3100	015391	045.6974	0
3200	015885	045.8553	0
3300	016382	046.0081	0
3400	016879	046.1565	0
3500	017376	046.3005	0
3600	017872	046.4404	0
3700	018369	046.5765	0
3800	018866	046.7090	0
3900	019363	046.8381	0
4000	019860	046.9638	0
4100	020354	047.0864	0
4200	020850	047.2061	0
4300	021347	047.3230	0
4400	021844	047.4372	0
4500	022341	047.5489	0
4600	022838	047.6581	0
4700	023334	047.7649	0
4800	023831	047.8695	0
4900	024328	047.9719	0
5000	024822	048.0723	0
5100	025319	048.1707	0
5200	025815	048.2671	0
5300	026312	048.3618	0
5400	026809	048.4546	0
5500	027306	048.5458	0
5600	027803	048.6353	0
5700	028299	048.7232	0
5800	028796	048.8097	0
5900	029290	048.8946	0
6000	029787	048.9781	0
6100	030284	049.0602	0
6200	030780	049.1410	0
6300	031277	049.2205	0
6400	031774	049.2987	0
6500	032271	049.3758	0

TABLE II

ARGON (A)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
6600	032768	049.4516	0
6700	033264	049.5263	0
6800	033758	049.5999	0
6900	034255	049.6724	0
7000	034752	049.7439	0
7100	035249	049.8144	0
7200	035746	049.8838	0
7300	036242	049.9524	0
7400	036739	050.0200	
7500	037236	050.0866	0
7600	037733	050.1524	0
7700	038227	050.2175	0
7800	038723	050.2816	0
7900	039220	050.3449	0
8000	039717	050.4074	0
8100	040214	050.4691	0
8200	040711	050.5300	
8300	041207	050.5902	0
8400	041704	050.6497	0
8500	042201	050.7085	0
8600	042695	050.7666	0
8700	043192	050.8241	0
8800	043688	050.8809	0
8900	044185	050.9370	0
9000	044682	050.9925	0
9100	045179	051.0474	0
9200	045676	051.1017	0
9300	046172	051.1554	0
9400	046669	051.2085	0
9500	047166	051.2611	0
9600	047663	051.3131	0
9700	048160	051.3646	0
9800	048656	051.4156	0
9900	049153	051.4660	0

TABLE III

BORON (B)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
100	000509	032.9974	0
150	000761	035.0438	0
200	001013	036.4957	0
250	001266	037.6219	0
300	0.01522	033.7181	0
350	001774	034.4941	0
400	002025	035.1663	0
450	002277	035.7592	0
500	002529	036.2896	0
537	002715	036.6489	0
600	003032	037.2074	0
700	002602	037.9679	0
800	003103	038.6363	0
900	004521	039.1110	0
1000	005020	039.6373	0
1100	005511	040.0615	0
1200	006009	040.4949	0
1300	006507	040.8936	0
1400	007005	041.2627	0
1500	007503	041.6064	0
1600	007993	042.0761	0
1700	008491	042.3777	0
1800	008988	042.6620	0
1900	009486	042.9309	0
2000	009980	043.1648	0
2100	010477	043.4074	0
2200	010974	043.6387	0
2300	011471	043.8597	0
2400	011968	044.0713	0
2500	012458	044.2922	0
2600	012957	044.4878	0
2700	013456	044.6760	0
2800	013954	044.8573	0
2900	014453	045.0324	0
3000	014952	045.2014	0

TABLE III

BORON (B)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
3100	015450	045.3649	0
3200	015935	045.5197	0
3300	016432	045.6726	0
3400	016929	045.8209	0
3500	017426	045.9650	0
3600	017923	046.1050	0
3700	018420	046.2411	0
3800	018917	046.3736	0
3900	019414	046.5027	0
4000	019911	046.6285	0
4100	020403	046.7513	0
4200	020900	046.8710	0
4300	021396	046.9879	0
4400	021893	047.1022	0
4500	022390	047.2138	0
4600	022887	047.3230	0
4700	023384	047.4299	0
4800	023881	047.5345	0
4900	024378	047.6370	0
5000	024875	047.7366	0
5100	025372	047.8350	0
5200	025869	047.9315	0
5300	026366	048.0261	0
5400	026863	048.1190	0
5500	027360	048.2102	0
5600	027857	048.2997	0
5700	028354	048.3877	0
5800	028851	048.4741	0
5900	029343	048.5080	0
6000	029840	048.5915	0
6100	030337	048.6737	0
6200	030834	048.7545	0
6300	031331	048.8340	0
6400	031828	048.9122	0
6500	032325	048.9893	0

TABLE III

BORON (B)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
6600	032822	049.0651	0
6700	033319	049.1398	0
6800	033809	049.2650	0
6900	034306	049.3376	0
7000	034802	049.4090	0
7100	035299	049.4795	0
7200	035796	049.5490	0
7300	036293	049.6175	0
7400	036790	049.6851	0
7500	037286	049.7518	0
7600	037783	049.8176	0
7700	038283	049.8503	0
7800	038780	049.9144	0
7900	039277	049.9777	0
8000	039774	050.0402	0
8100	040271	050.1019	0
8200	040767	050.1629	0
8300	041264	050.2232	0
8400	041761	050.2827	0
8500	042258	050.3415	0
8600	042749	050.4311	0
8700	043245	050.4885	0
8800	043742	050.5453	0
8900	044239	050.6014	0
9000	044736	050.6570	0
9100	045233	050.7119	0
9200	045730	050.7662	0
9300	046227	050.8199	0
9400	046724	050.8730	0
9500	047221	050.9256	0
9600	047717	050.9776	0
9700	048214	051.0291	0
9800	048711	051.0801	0
9900	049208	051.1306	0

TABLE IV

BORON OXIDE (BO)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
100	000675	042.5086	-010064
150	001021	045.3205	-009590
200	001368	047.3156	-009088
250	001715	048.8631	-008567
300	002075	044.5434	-007789
350	002424	045.6188	-007201
400	002773	046.5503	-006602
450	003122	047.3719	-005993
500	003471	048.1069	-005375
537	003729	048.6049	-004912
600	004168	049.3788	-004116
700	003595	050.4650	-003185
800	004302	051.4080	-001879
900	006307	052.1290	-000175
1000	007031	052.8922	001166
1100	007757	053.6552	002399
1200	008519	054.3161	003757
1300	009281	054.9280	005126
1400	010043	055.4926	006505
1500	010805	056.0183	007893
1600	011604	056.6069	009422
1700	012415	057.0985	010833
1800	013226	057.5620	012251
1900	014037	058.0004	013673
2000	014884	058.3917	015149
2100	015716	058.7976	016582
2200	016548	059.1845	018020
2300	017379	059.5543	019463
2400	018211	059.9083	020909
2500	019031	060.2861	022306
2600	019886	060.6214	023758
2700	020741	060.9440	025213
2800	021596	061.2549	026670
2900	022451	061.5549	028131
3000	023305	061.8447	029595

TABLE IV

BORON OXIDE (BO)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
3100	024160	062.1250	031061
3200	025030	062.4028	032531
3300	025906	062.6722	034002
3400	026781	062.9335	035475
3500	027657	063.1873	036950
3600	028532	063.4340	038427
3700	029408	063.6738	039906
3800	030283	063.9073	041387
3900	031159	064.1347	042869
4000	032034	064.3564	044354
4100	032912	064.5748	045843
4200	033799	064.7886	047331
4300	034687	064.9975	048821
4400	035574	065.2015	050313
4500	036462	065.4009	051807
4600	037349	065.5960	053302
4700	038237	065.7869	054799
4800	039124	065.9737	056298
4900	040012	066.1567	057798
5000	040819	066.3027	059385
5100	041715	066.4801	060891
5200	042610	066.6540	062399
5300	043506	066.8246	063909
5400	044402	066.9920	065420
5500	045297	067.1564	066932
5600	046193	067.3178	068446
5700	047089	067.4763	069961
5800	047984	067.6321	071478
5900	047885	067.7149	072122
6000	048786	067.8663	073644
6100	049687	068.0153	075167
6200	050588	068.1618	076691
6300	051489	068.3060	078217
6400	052390	068.4479	079744
6500	053291	068.5876	081272

TABLE IV

BORON OXIDE (BO)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
6600	054192	068.7251	082801
6700	055093	068.8607	084332
6800	057084	069.1018	086582
6900	057990	069.2341	088110
7000	058897	069.3645	089639
7100	059803	069.4931	091169
7200	060710	069.6199	092701
7300	061616	069.7449	094233
7400	062523	069.8683	095767
7500	063429	069.9900	097302
7600	064336	070.1100	098839
7700	065205	070.1760	100496
7800	066117	070.2937	102037
7900	067029	070.4099	103578
8000	067941	070.5246	105121
8100	068853	070.6380	106665
8200	069765	070.7499	108210
8300	070677	070.8604	109756
8400	071589	070.9697	111304
8500	072501	071.0776	112852
8600	073453	071.2397	114244
8700	074371	071.3458	115792
8800	075288	071.4507	117341
8900	076206	071.5544	118891
9000	077124	071.6570	120442
9100	078042	071.7584	121994
9200	078959	071.8587	123547
9300	079877	071.9579	125101
9400	080795	072.0560	126655
9500	081712	072.1531	128211
9600	082630	072.2492	129768
9700	083548	072.3443	131325
9800	084465	072.4384	132883
9900	085383	072.5316	134443

TABLE V

BORON TRIOXIDE (B_2O_3)

T °R	$H°-H°_o$	S°	$\Delta F°_f$
100	000715	049.8600	-542289
150	001235	054.0768	-541485
200	001755	057.0687	-540687
250	002275	059.3894	-539893
300	000935	053.4234	-541505
350	001589	055.4381	-540816
400	002242	057.1834	-540149
450	002896	058.7228	-539500
500	003549	060.0999	-538869
537	004033	061.0329	-538411
600	004856	062.4828	-537649
700	005617	064.5462	-535215
800	007132	066.5692	-534111
900	010631	068.7710	-533505
1000	012344	070.5760	-532598
1100	015890	073.0985	-531005
1200	017818	074.7763	-530344
1300	019747	076.3197	-529760
1400	021675	077.7486	-529248
1500	023603	079.0789	-528803
1600	040917	080.0115	-512045
1700	043168	081.3765	-511669
1800	045420	082.6635	-511368
1900	047671	083.8809	-511136
2000	033375	084.6880	-526901
2100	035694	085.8196	-526770
2200	038013	086.8985	-526701
2300	040332	087.9295	-526693
2400	042652	088.9166	-526743
2500	045452	090.3075	-527372
2600	047873	091.2571	-527573
2700	050294	092.1710	-527828
2800	052716	093.0515	-528136
2900	055137	093.9012	-528495
3000	057558	094.7221	-528903

TABLE V

BORON TRIOXIDE (B_2O_3)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
3100	059980	095.5160	-529358
3200	062460	096.3103	-529877
3300	064949	097.0762	-530427
3400	067438	097.8193	-531023
3500	069927	098.5408	-531663
3600	072416	099.2419	-532345
3700	074905	099.9239	-533069
3800	077394	100.5877	-533833
3900	079883	101.2342	-534636
4000	082372	101.8644	-535478
4100	084881	102.4883	-536366
4200	087402	103.0960	-537283
4300	089924	103.6894	-538237
4400	092446	104.2692	-539226
4500	094968	104.8360	-540249
4600	097490	105.3902	-541307
4700	100012	105.9326	-542398
4800	102534	106.4636	-543521
4900	105056	106.9835	-544677
5000	107578	107.4959	-545886
5100	110119	107.9990	-547104
5200	112659	108.4922	-548352
5300	115199	108.9761	-549629
5400	117739	109.4510	-550936
5500	120280	109.9171	-552272
5600	122820	110.3748	-553635
5700	125360	110.8244	-555027
5800	127901	111.2662	-556445
5900	130437	111.7032	-558504
6000	132988	112.1320	-559986
6100	135540	112.5538	-561494
6200	138091	112.9687	-563027
6300	140643	113.3769	-564585
6400	143195	113.7788	-566169
6500	145746	114.1744	-567776

TABLE V

BORON TRIOXIDE (B_2O_3)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
6600	148298	114.5639	-569408
6700	150849	114.9477	-571063
6800	153392	115.3263	-572040
6900	155951	115.6998	-573731
7000	158509	116.0680	-575445
7100	161068	116.4310	-577181
7200	163627	116.7889	-578939
7300	166186	117.1418	-580719
7400	168745	117.4900	-582520
7500	171304	117.8335	-584343
7600	173863	118.1724	-586186
7700	176407	118.5064	-588564
7800	178971	118.8373	-590454
7900	181535	119.1639	-592365
8000	184099	119.4864	-594296
8100	186663	119.8049	-596246
8200	189227	120.1196	-598216
8300	191791	120.4303	-600205
8400	194355	120.7374	-602213
8500	196919	121.0409	-604239
8600	199472	121.3457	-605784
8700	202039	121.6425	-607841
8800	204607	121.9359	-609917
8900	207174	122.2261	-612010
9000	209742	122.5130	-614121
9100	212310	122.7967	-616250
9200	214877	123.0773	-618396
9300	217445	123.3549	-620559
9400	220012	123.6295	-622739
9500	222580	123.9012	-624935
9600	225148	124.1700	-627149
9700	227715	124.4361	-629378
9800	230283	124.6995	-631624
9900	232850	124.9601	-633886

TABLE VI

CARBON (C)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
100	000109	000.0131	0
150	000129	000.1465	0
200	000148	000.2599	0
250	000168	000.3478	0
300	000037	000.1580	0
350	000066	000.4765	0
400	000169	000.7523	0
450	000272	000.9957	0
500	000375	001.2134	0
537	000452	001.3608	0
600	000582	001.5900	
700	000847	002.0006	0
800	001132	002.3813	0
900	001476	003.4960	0
1000	001755	003.7897	0
1100	002257	003.8696	0
1200	002669	004.2287	0
1300	003082	004.5590	0
1400	003495	004.8648	0
1500	003908	005.1496	0
1600	004362	004.4515	0
1700	004946	004.8059	0
1800	005531	005.1400	
1900	006116	005.4561	0
2000	006561	005.6698	0
2100	007103	005.9343	0
2200	007645	006.1864	0
2300	008187	006.4273	0
2400	008729	006.6580	0
2500	009306	007.6137	0
2600	009882	007.8396	0
2700	010458	008.0571	0
2800	011034	008.2666	0
2900	011610	008.4687	0
3000	012186	008.6640	0

TABLE VI

CARBON (C)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
3100	012762	008.8529	0
3200	013373	009.0474	0
3300	013978	009.2335	0
3400	014583	009.4141	0
3500	015188	009.5895	0
3600	015793	009.7599	0
3700	016398	009.9257	0
3800	017003	010.0871	0
3900	017608	010.2442	0
4000	018213	010.3974	0
4100	018812	010.5471	0
4200	019438	010.6980	0
4300	020064	010.8453	0
4400	020690	010.9892	0
4500	021316	011.1299	0
4600	021942	011.2674	0
4700	022568	011.4021	0
4800	023194	011.5339	0
4900	023820	011.6629	0
5000	024470	011.7959	0
5100	025112	011.9230	0
5200	025754	012.0477	0
5300	026396	012.1700	
5400	027038	012.2900	
5500	027680	012.4078	0
5600	028322	012.5235	0
5700	028964	012.6371	0
5800	029606	012.7488	0
5900	030236	012.8590	0
6000	030893	012.9694	0
6100	031550	013.0780	0
6200	032207	013.1848	0
6300	032864	013.2899	0
6400	033521	013.3934	0
6500	034178	013.4953	0

TABLE VI

CARBON (C)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
6600	034835	013.5956	0
6700	035492	013.6944	0
6800	036166	013.7958	0
6900	036838	013.8939	0
7000	037510	013.9906	0
7100	038182	014.0860	0
7200	038854	014.1799	0
7300	039526	014.2726	0
7400	040198	014.3641	0
7500	040870	014.4543	0
7600	041542	014.5433	0
7700	041964	014.6335	0
7800	042648	014.7218	0
7900	043332	014.8089	0
8000	044016	014.8950	0
8100	044700	014.9800	
8200	045384	015.0639	0
8300	046068	015.1468	0
8400	046752	015.2287	0
8500	047436	015.3097	0
8600	047594	015.3249	0
8700	048287	015.4050	0
8800	048980	015.4842	0
8900	049673	015.5625	0
9000	050366	015.6399	0
9100	051059	015.7165	0
9200	051752	015.7923	0
9300	052445	015.8672	0
9400	053138	015.9413	0
9500	053831	016.0146	0
9600	054524	016.0872	0
9700	055217	016.1590	0
9800	055910	016.2301	0
9900	056603	016.3004	0

TABLE VII

CARBON MONOXIDE (CO)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
100	000691	035.5266	-050415
150	001039	038.3467	-051292
200	001386	040.3476	-052222
250	001734	041.8996	-053191
300	002077	043.1606	-054044
350	002425	044.2343	-055077
400	002774	045.1644	-056119
450	003122	045.9847	-057170
500	003470	046.7186	-058229
537	003728	047.2158	-059017
600	004167	047.9885	-060367
700	004867	049.0691	-062522
800	005568	050.0055	-064688
900	006277	050.8425	-066220
1000	006989	051.5926	-068321
1100	007704	052.2770	-070858
1200	008449	052.9252	-072984
1300	009194	053.5215	-075105
1400	009939	054.0736	-077221
1500	010684	054.5876	-079333
1600	011466	055.0969	-083030
1700	012259	055.5777	-085227
1800	013053	056.0310	-087412
1900	013846	056.4598	-089585
2000	014643	056.8690	-091781
2100	015460	057.2675	-093943
2200	016276	057.6475	-096098
2300	017093	058.0105	-098246
2400	017910	058.3581	-100388
2500	018746	058.7018	-100725
2600	019588	059.0320	-102781
2700	020429	059.3497	-104830
2800	021271	059.6558	-106873
2900	022113	059.9512	-108910
3000	022955	060.2366	-110941

TABLE VII

CARBON MONOXIDE (CO)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
3100	023797	060.5126	-112966
3200	024657	060.7876	-114935
3300	025523	061.0541	-116998
3400	026389	061.3127	-119006
3500	027256	061.5638	-121008
3600	028122	061.8078	-123005
3700	028988	062.0452	-124996
3800	029854	062.2762	-126982
3900	030721	062.5012	-128963
4000	031587	062.7205	-130939
4100	032462	062.9380	-132904
4200	033342	063.1500	-134871
4300	034222	063.3571	-136833
4400	035102	063.5595	-138789
4500	035982	063.7573	-140741
4600	036862	063.9507	-142689
4700	037742	064.1400	-144631
4800	038623	064.3253	-146570
4900	039503	064.5068	-148503
5000	040386	064.6863	-150426
5100	041276	064.8625	-152351
5200	042165	065.0352	-154271
5300	043055	065.2046	-156186
5400	043944	065.3709	-158097
5500	044834	065.5341	-160004
5600	045723	065.6944	-161907
5700	046612	065.8518	-163806
5800	047502	066.0065	-165700
5900	048391	066.1601	-167582
6000	049288	066.3107	-169469
6100	050184	066.4589	-171351
6200	051080	066.6046	-173230
6300	051976	066.7480	-175104
6400	052872	066.8892	-176974
6500	053769	067.0281	-178841

TABLE VII

CARBON MONOXIDE (CO)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
6600	054665	067.1649	-180703
6700	055561	067.2997	-182562
6800	056455	067.4311	-184397
6900	057356	067.5627	-186247
7000	058257	067.6924	-188094
7100	059159	067.8202	-189937
7200	060060	067.9463	-191776
7300	060962	068.0706	-193612
7400	061863	068.1933	-195444
7500	062764	068.3143	-197272
7600	063666	068.4337	-199097
7700	064564	068.5526	-200657
7800	065470	068.6695	-202474
7900	066376	068.7849	-204288
8000	067282	068.8989	-206098
8100	068188	069.0114	-207905
8200	069094	069.1226	-209708
8300	070000	069.2324	-211508
8400	070906	069.3409	-213305
8500	071812	069.4481	-215098
8600	072714	069.5536	-216915
8700	073624	069.6588	-218708
8800	074534	069.7628	-220497
8900	075444	069.8656	-222284
9000	076354	069.9673	-224067
9100	077264	070.0678	-225846
9200	078174	070.1673	-227623
9300	079084	070.2656	-229396
9400	079994	070.3630	-231166
9500	080904	070.4593	-232934
9600	081814	070.5545	-234698
9700	082724	070.6488	-236459
9800	083633	070.7422	-238217
9900	084543	070.8345	-239972

TABLE VIII

CARBON DIOXIDE (CO_2)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
100	000692	038.6534	-169386
150	001041	041.4838	-169450
200	001390	043.4920	-169507
250	001739	045.0497	-169560
300	001923	045.9029	-169497
350	002366	047.2710	-169537
400	002810	048.4561	-169576
450	003254	049.5015	-169613
500	003698	050.4366	-169649
537	004026	051.0702	-169675
600	004585	052.0547	-169718
700	005549	053.5458	-169784
800	006537	054.8647	-169847
900	007597	056.1159	-169272
1000	008664	057.2396	-169263
1100	009764	058.2956	-169692
1200	010949	059.3263	-169710
1300	012133	060.2745	-169727
1400	013318	061.1524	-169743
1500	014502	061.9697	-169758
1600	015789	062.8085	-171364
1700	017087	063.5954	-171474
1800	018385	064.3373	-171578
1900	019683	065.0391	-171674
2000	020992	065.7117	-171798
2100	022339	066.3687	-171893
2200	023686	066.9951	-171985
2300	025032	067.5936	-172076
2400	026379	068.1667	-172164
2500	027765	068.7385	-170460
2600	029160	069.2857	-170472
2700	030555	069.8123	-170482
2800	031950	070.3197	-170490
2900	033346	070.8093	-170496
3000	034741	071.2823	-170500

TABLE VIII

CARBON DIOXIDE (CO_2)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
3100	036136	071.7398	-170503
3200	037569	072.1972	-170501
3300	039012	072.6410	-170499
3400	040454	073.0716	-170496
3500	041896	073.4897	-170490
3600	043339	073.8960	-170483
3700	044781	074.2911	-170474
3800	046223	074.6758	-170463
3900	047666	075.0504	-170450
4000	049108	075.4156	-170436
4100	050565	075.7794	-170420
4200	052034	076.1334	-170403
4300	053503	076.4791	-170383
4400	054972	076.8169	-170362
4500	056441	077.1470	-170338
4600	057911	077.4699	-170312
4700	059380	077.7859	-170285
4800	060849	078.0952	-170256
4900	062318	078.3981	-170225
5000	063792	078.6971	-170183
5100	065279	078.9916	-170147
5200	066766	079.2804	-170109
5300	068253	079.5637	-170069
5400	069741	079.8417	-170027
5500	071228	080.1146	-169983
5600	072715	080.3825	-169937
5700	074202	080.6458	-169889
5800	075689	080.9044	-169840
5900	077177	081.1605	-169777
6000	078678	081.4127	-169723
6100	080178	081.6608	-169667
6200	081679	081.9047	-169609
6300	083179	082.1448	-169548
6400	084680	082.3811	-169486
6500	086180	082.6138	-169421

TABLE VIII

CARBON DIOXIDE (CO_2)

T °R	$H°-H°_0$	S°	$\Delta F°_f$
6600	087681	082.8429	-169355
6700	089181	083.0685	-169286
6800	090680	083.2917	-169207
6900	092192	083.5124	-169133
7000	093704	083.7300	-169058
7100	095215	083.9444	-168980
7200	096727	084.1559	-168900
7300	098239	084.3644	-168818
7400	099751	084.5701	-168734
7500	101263	084.7731	-168648
7600	102775	084.9733	-168560
7700	104283	085.1718	-168203
7800	105804	085.3681	-168110
7900	107326	085.5620	-168016
8000	108848	085.7534	-167919
8100	110369	085.9424	-167820
8200	111891	086.1291	-167719
8300	113412	086.3135	-167615
8400	114934	086.4957	-167510
8500	116456	086.6758	-167403
8600	117974	086.8542	-167326
8700	119504	087.0311	-167221
8800	121035	087.2061	-167114
8900	122565	087.3790	-167006
9000	124096	087.5500	-166895
9100	125626	087.7191	-166782
9200	127157	087.8864	-166667
9300	128687	088.0519	-166550
9400	130218	088.2156	-166432
9500	131749	088.3775	-166311
9600	133279	088.5378	-166189
9700	134810	088.6964	-166065
9800	136340	088.8534	-165939
9900	137871	089.0088	-165811

TABLE IX

ATOMIC HYDROGEN (H)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
100	000496	019.0455	092101
150	000744	021.0599	091655
200	000992	022.4891	091170
250	001241	023.5977	090656
300	001486	024.5005	090128
350	001735	025.2663	089577
400	001983	025.9297	089015
450	002232	026.5148	088443
500	002480	027.0382	087863
537	002664	027.3929	087429
600	002977	027.9440	086681
700	003475	028.7129	085474
800	003972	029.3763	084245
900	004468	029.9614	082997
1000	004965	030.4848	081734
1100	005460	030.9583	080455
1200	005957	031.3906	079164
1300	006454	031.7883	077860
1400	006951	032.1564	076545
1500	007447	032.4992	075220
1600	007942	032.8198	073883
1700	008439	033.1210	072539
1800	008936	033.4050	071187
1900	009433	033.6736	069828
2000	009928	033.9284	068463
2100	010425	034.1708	067090
2200	010922	034.4019	065712
2300	011419	034.6227	064327
2400	011916	034.8342	062937
2500	012411	035.0369	061543
2600	012907	035.2317	060144
2700	013404	035.4192	058740
2800	013901	035.5999	057332
2900	014398	035.7742	055920
3000	014895	035.9426	054505

TABLE IX

ATOMIC HYDROGEN (H)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
3100	015391	036.1055	053085
3200	015885	036.2635	051663
3300	016382	036.4163	050237
3400	016879	036.5646	048809
3500	017376	036.7086	047378
3600	017872	036.8486	045945
3700	018369	036.9847	044509
3800	018866	037.1172	043071
3900	019363	037.2463	041631
4000	019860	037.3720	040189
4100	020354	037.4946	038745
4200	020850	037.6143	037299
4300	021347	037.7312	035851
4400	021844	037.8454	034402
4500	022341	037.9571	032951
4600	022838	038.0663	031498
4700	023334	038.1731	030044
4800	023831	038.2777	028588
4900	024328	038.3801	027131
5000	024822	038.4805	025672
5100	025319	038.5789	024213
5200	025815	038.6753	022752
5300	026312	038.7700	021291
5400	026809	038.8628	019828
5500	027306	038.9540	018365
5600	027803	039.0435	016900
5700	028299	039.1314	015435
5800	028796	039.2178	013969
5900	029290	039.3028	012505
6000	029787	039.3863	011037
6100	030284	039.4684	009568
6200	030780	039.5492	008099
6300	031277	039.6287	006629
6400	031774	039.7069	005159
6500	032271	039.7840	003687

TABLE IX

ATOMIC HYDROGEN (H)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
6600	032768	039.8598	002216
6700	033264	039.9345	000743
6800	033758	040.0081	-000730
6900	034255	040.0806	-002204
7000	034752	040.1521	-003677
7100	035249	040.2225	-005152
7200	035746	040.2920	-006627
7300	036242	040.3605	-008102
7400	036739	040.4281	-009577
7500	037236	040.4948	-011053
7600	037733	040.5606	-012530
7700	038227	040.6257	-014006
7800	038723	040.6898	-015483
7900	039220	040.7530	-016960
8000	039717	040.8155	-018438
8100	040214	040.8773	-019915
8200	040711	040.9382	-021393
8300	041207	040.9984	-022871
8400	041704	041.0579	-024350
8500	042201	041.1167	-025829
8600	042695	041.1748	-027304
8700	043192	041.2323	-028783
8800	043688	041.2890	-030262
8900	044185	041.3452	-031741
9000	044682	041.4007	-033221
9100	045179	041.4556	-034700
9200	045676	041.5099	-036180
9300	046172	041.5636	-037659
9400	046669	041.6167	-039139
9500	047166	041.6693	-040619
9600	047663	041.7213	-042098
9700	048160	041.7728	-043578
9800	048656	041.8237	-045058
9900	049153	041.8742	-046539

TABLE X

MOLECULAR HYDROGEN (H_2)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
100	000933	021.2168	0
150	001203	023.4036	0
200	001473	024.9551	0
250	001742	026.1586	0
300	002007	027.1961	0
350	002351	028.2583	0
400	002696	029.1784	0
450	003041	029.9900	
500	003385	030.7160	0
537	003640	031.2079	0
600	004074	031.9723	0
700	004773	033.0533	0
800	005470	033.9847	0
900	006169	034.8077	0
1000	006868	035.5445	0
1100	007565	036.2110	0
1200	008269	036.8232	0
1300	008972	037.3865	0
1400	009676	037.9079	0
1500	010380	038.3934	0
1600	011087	038.8499	0
1700	011809	039.2876	0
1800	012531	039.7002	0
1900	013253	040.0906	0
2000	013976	040.4636	0
2100	014716	040.8250	0
2200	015457	041.1695	0
2300	016198	041.4988	0
2400	016938	041.8140	0
2500	017698	042.1266	0
2600	018470	042.4294	0
2700	019242	042.7208	0
2800	020014	043.0015	0
2900	020786	043.2725	0
3000	021558	043.5342	0

TABLE X

MOLECULAR HYDROGEN (H_2)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
3100	022330	043.7873	0
3200	023127	044.0428	0
3300	023947	044.2950	0
3400	024766	044.5396	0
3500	025586	044.7772	0
3600	026405	045.0080	0
3700	027225	045.2326	0
3800	028044	045.4511	0
3900	028864	045.6640	0
4000	029683	045.8715	0
4100	030523	046.0807	0
4200	031380	046.2871	0
4300	032236	046.4886	0
4400	033093	046.6855	0
4500	033949	046.8780	0
4600	034806	047.0662	0
4700	035662	047.2504	0
4800	036519	047.4308	0
4900	037375	047.6074	0
5000	038245	047.7840	0
5100	039131	047.9594	0
5200	040017	048.1314	0
5300	040903	048.3002	0
5400	041789	048.4658	0
5500	042675	048.6283	0
5600	043561	048.7879	0
5700	044447	048.9447	0
5800	045333	049.0988	0
5900	046230	049.2544	0
6000	047142	049.4077	0
6100	048054	049.5585	0
6200	048967	049.7069	0
6300	049879	049.8528	0
6400	050791	049.9965	0
6500	051703	050.1380	0

TABLE X

MOLECULAR HYDROGEN (H_2)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
6600	052616	050.2772	0
6700	053528	050.4144	0
6800	054447	050.5509	0
6900	055381	050.6873	0
7000	056315	050.8217	0
7100	057249	050.9542	0
7200	058183	051.0849	0
7300	059118	051.2138	0
7400	060052	051.3409	0
7500	060986	051.4663	0
7600	061920	051.5900	
7700	062860	051.7140	0
7800	063816	051.8372	0
7900	064771	051.9589	0
8000	065726	052.0791	0
8100	066681	052.1977	0
8200	067637	052.3149	0
8300	068592	052.4307	0
8400	069547	052.5451	0
8500	070502	052.6582	0
8600	071463	052.7720	0
8700	072438	052.8847	0
8800	073413	052.9961	0
8900	074388	053.1062	0
9000	075363	053.2152	0
9100	076338	053.3229	0
9200	077313	053.4295	0
9300	078288	053.5349	0
9400	079263	053.6391	0
9500	080237	053.7423	0
9600	081212	053.8444	0
9700	082187	053.9454	0
9800	083162	054.0454	0
9900	084137	054.1444	0

TABLE XI

WATER VAPOR (H_2O)

T °R	$H°-H°_0$	$S°$	$\Delta F°_f$
100	000777	031.7159	-102478
150	001175	034.9436	-102060
200	001573	037.2336	-101627
250	001971	039.0099	-101182
300	002355	040.4314	-100710
350	002756	041.6685	-100239
400	003158	042.7401	-099751
450	003559	043.6853	-099249
500	003960	044.5309	-098733
537	004257	045.1038	-098343
600	004763	045.9941	-097656
700	005576	047.2519	-096558
800	006395	048.3450	-095417
900	007233	049.3328	-094246
1000	008074	050.2194	-093050
1100	008922	051.0318	-091832
1200	009818	051.8109	-090593
1300	010713	052.5276	-089338
1400	011608	053.1912	-088067
1500	012504	053.8090	-086781
1600	013456	054.4301	-085490
1700	014441	055.0272	-084183
1800	015426	055.5903	-082866
1900	016411	056.1229	-081541
2000	017407	056.6354	-080206
2100	018451	057.1450	-078866
2200	019495	057.6308	-077520
2300	020540	058.0950	-076169
2400	021584	058.5395	-074812
2500	022687	058.9925	-073450
2600	023810	059.4331	-072085
2700	024933	059.8570	-070717
2800	026056	060.2655	-069346
2900	027180	060.6597	-067972
3000	028303	061.0405	-066595

TABLE XI

WATER VAPOR (H_2O)

T °R	$H°-H°_o$	$S°$	$\Delta F°_f$
3100	029426	061.4088	-065215
3200	030621	061.7939	-063839
3300	031843	062.1698	-062456
3400	033064	062.5344	-061071
3500	034285	062.8884	-059684
3600	035507	063.2325	-058296
3700	036728	063.5671	-056907
3800	037949	063.8928	-055517
3900	039171	064.2100	-054125
4000	040392	064.5193	-052732
4100	041658	064.8348	-051338
4200	042944	065.1448	-049944
4300	044231	065.4475	-048548
4400	045517	065.7432	-047151
4500	046803	066.0322	-045754
4600	048089	066.3149	-044356
4700	049376	066.5916	-042957
4800	050662	066.8624	-041557
4900	051948	067.1276	-040157
5000	053261	067.3950	-038760
5100	054591	067.6585	-037358
5200	055921	067.9168	-035956
5300	057252	068.1702	-034553
5400	058582	068.4188	-033150
5500	059912	068.6630	-031746
5600	061243	068.9027	-030341
5700	062573	069.1381	-028936
5800	063903	069.3695	-027530
5900	065254	069.5964	-026084
6000	066616	069.8252	-024676
6100	067977	070.0503	-023268
6200	069339	070.2717	-021859
6300	070700	070.4895	-020449
6400	072062	070.7039	-019039
6500	073423	070.9150	-017629

TABLE XI

WATER VAPOR (H_2O)

T °R	$H°-H°_o$	S°	$\Delta F°_f$
6600	074785	071.1229	-016217
6700	076146	071.3276	-014805
6800	077512	071.5368	-013434
6900	078897	071.7390	-012021
7000	080282	071.9383	-010608
7100	081667	072.1348	-009194
7200	083051	072.3285	-007780
7300	084436	072.5195	-006364
7400	085821	072.7079	-004949
7500	087206	072.8938	-003532
7600	088591	073.0773	-002115
7700	089984	073.2570	-000668
7800	091386	073.4380	000750
7900	092789	073.6168	002170
8000	094192	073.7932	003590
8100	095595	073.9675	005010
8200	096998	074.1396	006432
8300	098401	074.3097	007854
8400	099804	074.4777	009277
8500	101207	074.6437	010701
8600	102608	074.8121	012101
8700	104026	074.9760	013526
8800	105443	075.1380	014951
8900	106860	075.2982	016378
9000	108278	075.4565	017804
9100	109695	075.6131	019232
9200	111112	075.7680	020660
9300	112530	075.9213	022090
9400	113947	076.0729	023519
9500	115365	076.2229	024950
9600	116782	076.3713	026381
9700	118199	076.5181	027813
9800	119617	076.6635	029245
9900	121034	076.8074	030678

TABLE XII

ATOMIC NITROGEN (N)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
100	000496	028.2671	152243
150	000744	030.2815	151665
200	000992	031.7107	151062
250	001241	032.8193	150441
300	001486	033.7219	149803
350	001735	034.4877	149154
400	001983	035.1511	148494
450	002232	035.7362	147825
500	002480	036.2596	147147
537	002664	036.6143	146641
600	002977	037.1654	145771
700	003475	037.9346	144369
800	003972	038.5979	142946
900	004468	039.1830	141505
1000	004965	039.7064	140048
1100	005460	040.1799	138577
1200	005957	040.6122	137093
1300	006454	041.0099	135599
1400	006951	041.3780	134095
1500	007447	041.7208	132581
1600	007942	042.0414	131061
1700	008439	042.3426	129532
1800	008936	042.6266	127998
1900	009433	042.8952	126457
2000	009928	043.1500	124911
2100	010425	043.3924	123360
2200	010922	043.6235	121805
2300	011419	043.8443	120245
2400	011916	044.0558	118681
2500	012411	044.2585	117115
2600	012907	044.4533	115544
2700	013404	044.6408	113971
2800	013901	044.8215	112394
2900	014398	044.9958	110814
3000	014895	045.1642	109232

TABLE XII

ATOMIC NITROGEN (N)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
3100	015391	045.3271	107647
3200	015885	045.4851	106060
3300	016382	045.6380	104470
3400	016879	045.7864	102879
3500	017376	045.9304	101286
3600	017873	046.0704	099690
3700	018370	046.2065	098093
3800	018867	046.3391	096494
3900	019364	046.4681	094893
4000	019860	046.5939	093291
4100	020354	046.7165	091687
4200	020852	046.8364	090081
4300	021349	046.9536	088474
4400	021847	047.0680	086866
4500	022345	047.1799	085256
4600	022843	047.2893	083645
4700	023341	047.3963	082033
4800	023838	047.5011	080419
4900	024336	047.6037	078804
5000	024830	047.7041	077187
5100	025331	047.8034	075570
5200	025832	047.9007	073952
5300	026333	047.9961	072332
5400	026834	048.0898	070712
5500	027335	048.1817	069090
5600	027836	048.2720	067467
5700	028337	048.3607	065843
5800	028838	048.4479	064218
5900	029337	048.5335	062593
6000	029845	048.6190	060966
6100	030354	048.7031	059338
6200	030863	048.7858	057709
6300	031371	048.8672	056080
6400	031880	048.9473	054449
6500	032389	049.0262	052817

TABLE XII

ATOMIC NITROGEN (N)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
6600	032897	049.1038	051184
6700	033406	049.1803	049550
6800	033914	049.2561	047915
6900	034435	049.3322	046279
7000	034957	049.4073	044642
7100	035478	049.4812	043004
7200	036000	049.5542	041365
7300	036521	049.6261	039726
7400	037043	049.6970	038085
7500	037564	049.7670	036443
7600	038085	049.8361	034800
7700	038609	049.9050	033155
7800	039148	049.9746	031510
7900	039687	050.0433	029864
8000	040227	050.1112	028217
8100	040766	050.1781	026569
8200	041305	050.2443	024920
8300	041844	050.3097	023270
8400	042384	050.3743	021618
8500	042923	050.4381	019966
8600	043468	050.5023	018310
8700	044029	050.5672	016656
8800	044590	050.6313	015000
8900	045151	050.6947	013343
9000	045712	050.7574	011684
9100	046273	050.8194	010025
9200	046834	050.8807	008364
9300	047395	050.9414	006702
9400	047956	051.0014	005039
9500	048517	051.0608	003374
9600	049079	051.1195	001709
9700	049640	051.1777	000042
9800	050201	051.2352	-001624
9900	050762	051.2922	-003293

TABLE XIII

MOLECULAR NITROGEN (N_2)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
100	000691	034.0741	0
150	001039	036.8945	0
200	001386	038.8956	0
250	001734	040.4478	0
300	002078	041.7096	0
350	002426	042.7826	0
400	002774	043.7121	0
450	003122	044.5320	0
500	003470	045.2654	0
537	003727	045.7624	0
600	004166	046.5346	0
700	004865	047.6146	0
800	005564	048.5481	0
900	006268	049.3791	0
1000	006975	050.1240	0
1100	007683	050.8011	0
1200	008418	051.4407	0
1300	009153	052.0290	0
1400	009888	052.5738	0
1500	010623	053.0809	0
1600	011391	053.5806	0
1700	012173	054.0544	0
1800	012954	054.5011	0
1900	013736	054.9236	0
2000	014522	055.3280	0
2100	015328	055.7213	0
2200	016134	056.0963	0
2300	016940	056.4546	0
2400	017746	056.7976	0
2500	018573	057.1370	0
2600	019406	057.4637	0
2700	020239	057.7780	0
2800	021071	058.0809	0
2900	021904	058.3731	0
3000	022737	058.6554	0

TABLE XIII

MOLECULAR NITROGEN (N_2)

T °R	$H^\circ - H^\circ_o$	S°	ΔF°_f
3100	023570	058.9285	0
3200	024423	059.2020	0
3300	025283	059.4666	0
3400	026143	059.7232	0
3500	027003	059.9725	0
3600	027863	060.2147	0
3700	028723	060.4503	0
3800	029582	060.6796	0
3900	030442	060.9029	0
4000	031302	061.1206	0
4100	032170	061.3366	0
4200	033045	061.5475	0
4300	033921	061.7535	0
4400	034796	061.9547	0
4500	035671	062.1514	0
4600	036547	062.3438	0
4700	037422	062.5320	0
4800	038297	062.7163	0
4900	039173	062.8968	0
5000	040050	063.0752	0
5100	040936	063.2505	0
5200	041821	063.4224	0
5300	042706	063.5910	0
5400	043591	063.7565	0
5500	044476	063.9189	0
5600	045362	064.0784	0
5700	046247	064.2351	0
5800	047132	064.3890	0
5900	048017	064.5414	0
6000	048909	064.6913	0
6100	049802	064.8388	0
6200	050694	064.9839	0
6300	051586	065.1267	0
6400	052478	065.2672	0
6500	053371	065.4055	0

TABLE XIII

MOLECULAR NITROGEN (N_2)

T °R	$H^\circ - H^\circ_c$	S°	ΔF°_f
6600	054263	065.5417	0
6700	055155	065.6759	0
6800	056046	065.8087	0
6900	056943	065.9397	0
7000	057841	066.0689	0
7100	058739	066.1962	0
7200	059636	066.3218	0
7300	060534	066.4456	0
7400	061432	066.5677	0
7500	062329	066.6882	0
7600	063227	066.8071	0
7700	064122	066.9248	0
7800	065024	067.0413	0
7900	065926	067.1562	0
8000	066829	067.2697	0
8100	067731	067.3817	0
8200	068633	067.4924	0
8300	069535	067.6018	0
8400	070437	067.7098	0
8500	071339	067.8166	0
8600	072238	067.9224	0
8700	073145	068.0272	0
8800	074051	068.1308	0
8900	074957	068.2331	0
9000	075863	068.3344	0
9100	076769	068.4345	0
9200	077675	068.5335	0
9300	078581	068.6315	0
9400	079487	068.7284	0
9500	080394	068.8243	0
9600	081300	068.9192	0
9700	082206	069.0131	0
9800	083112	069.1060	0
9900	084018	069.1980	0

TABLE XIV

NITRIC OXIDE (NO)

T °R	$H^\circ - H^\circ_c$	S°	ΔF°_f
100	000718	037.7368	038482
150	001104	040.8645	038371
200	001490	043.0837	038248
250	001875	044.8050	038115
300	002255	046.1837	037960
350	002612	047.2838	037836
400	002969	048.2369	037692
450	003325	049.0775	037546
500	003682	049.8294	037399
537	003946	050.3389	037290
600	004396	051.1307	037104
700	003773	052.2342	035469
800	004489	053.1905	035171
900	006554	054.0480	036210
1000	007283	054.8159	035911
1100	008014	055.5171	035609
1200	008780	056.1834	035309
1300	009546	056.7963	035009
1400	010311	057.3637	034708
1500	011077	057.8920	034407
1600	011876	058.4128	034104
1700	012689	058.9055	033803
1800	013501	059.3700	033501
1900	014314	059.8093	033199
2000	015128	060.2298	032893
2100	015962	060.6369	032590
2200	016797	061.0249	032287
2300	017631	061.3958	031984
2400	018465	061.7508	031681
2500	019318	062.0845	031418
2600	020174	062.4201	031116
2700	021030	062.7430	030814
2800	021885	063.0542	030512
2900	022741	063.3545	030210
3000	023597	063.6446	029907

TABLE XIV

NITRIC OXIDE (NO)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
3100	024452	063.9251	029605
3200	025326	064.2189	029258
3300	026203	064.4886	028954
3400	027080	064.7506	028650
3500	027957	065.0049	028347
3600	028835	065.2519	028043
3700	029712	065.4923	027739
3800	030589	065.7262	027436
3900	031466	065.9540	027133
4000	032343	066.1761	026830
4100	033227	066.3969	026524
4200	034117	066.6112	026221
4300	035006	066.8205	025919
4400	035896	067.0250	025617
4500	036785	067.2249	025315
4600	037675	067.4204	025013
4700	038564	067.6117	024712
4800	039454	067.7990	024411
4900	040343	067.9824	024110
5000	041243	068.1658	023807
5100	042141	068.3437	023506
5200	043039	068.5181	023207
5300	043937	068.6892	022907
5400	044835	068.8570	022608
5500	045733	069.0218	022309
5600	046631	069.1836	022011
5700	047529	069.3426	021713
5800	048427	069.4988	021416
5900	049316	069.6534	021109
6000	050221	069.8055	020813
6100	051125	069.9550	020517
6200	052030	070.1022	020221
6300	052935	070.2470	019926
6400	053840	070.3895	019631
6500	054745	070.5298	019337

TABLE XIV

NITRIC OXIDE (NO)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
6600	055650	070.6679	019044
6700	056555	070.8040	018750
6800	057466	070.9384	018467
6900	058377	071.0714	018175
7000	059288	071.2024	017883
7100	060198	071.3316	017592
7200	061109	071.4590	017301
7300	062020	071.5846	017011
7400	062930	071.7085	016721
7500	063841	071.8307	016431
7600	064752	071.9513	016143
7700	065684	072.0712	015876
7800	066599	072.1893	015588
7900	067515	072.3060	015301
8000	068431	072.4212	015014
8100	069347	072.5349	014727
8200	070263	072.6473	014441
8300	071178	072.7583	014156
8400	072094	072.8680	013871
8500	073010	072.9764	013586
8600	073989	073.0853	013356
8700	074910	073.1918	013072
8800	075831	073.2970	012789
8900	076752	073.4011	012506
9000	077673	073.5040	012223
9100	078593	073.6057	011941
9200	079514	073.7063	011659
9300	080435	073.8059	011378
9400	081356	073.9044	011098
9500	082277	074.0018	010817
9600	083197	074.0982	010537
9700	084118	074.1936	010258
9800	085039	074.2881	009979
9900	085960	074.3816	009700

TABLE XI

ATOMIC OXYGEN (O)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
100	000495	029.1371	104557
150	000778	031.4343	104009
200	001062	033.0641	103424
250	001345	034.3284	102812
300	001650	035.4196	102183
350	001912	036.2268	101529
400	002173	036.9261	100861
450	002435	037.5428	100184
500	002697	038.0945	099496
537	002891	038.4684	098982
600	003221	039.0493	098096
700	003737	039.8469	096668
800	004251	040.5325	095218
900	004758	041.1310	093749
1000	005266	041.6663	092265
1100	005771	042.1480	090769
1200	006273	042.5855	089261
1300	006776	042.9880	087744
1400	007279	043.3607	086219
1500	007782	043.7076	084686
1600	008279	044.0298	083148
1700	008779	044.3328	081603
1800	009279	044.6186	080054
1900	009779	044.8888	078500
2000	010278	045.1449	076941
2100	010777	045.3883	075379
2200	011275	045.6204	073813
2300	011774	045.8422	072244
2400	012273	046.0546	070672
2500	012770	046.2581	069098
2600	013268	046.4535	067520
2700	013766	046.6415	065941
2800	014265	046.8227	064358
2900	014763	046.9975	062774
3000	015261	047.1664	061188

TABLE XV

ATOMIC OXYGEN (O)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
3100	015759	047.3298	059599
3200	016254	047.4880	058009
3300	016751	047.6412	056417
3400	017249	047.7898	054824
3500	017747	047.9341	053230
3600	018245	048.0743	051634
3700	018742	048.2107	050037
3800	019240	048.3434	048438
3900	019738	048.4727	046839
4000	020236	048.5987	045238
4100	020730	048.7214	043637
4200	021228	048.8415	042035
4300	021726	048.9588	040431
4400	022225	049.0733	038827
4500	022723	049.1853	037222
4600	023221	049.2949	035616
4700	023720	049.4020	034010
4800	024218	049.5070	032402
4900	024716	049.6097	030794
5000	025212	049.7103	029187
5100	025712	049.8094	027578
5200	026212	049.9066	025968
5300	026713	050.0019	024358
5400	027213	050.0955	022748
5500	027714	050.1873	021137
5600	028214	050.2775	019526
5700	028715	050.3660	017915
5800	029215	050.4531	016303
5900	029713	050.5388	014690
6000	030217	050.6235	013078
6100	030721	050.7069	011465
6200	031225	050.7888	009852
6300	031729	050.8695	008239
6400	032234	050.9489	006625
6500	032738	051.0270	005011

TABLE XV

ATOMIC OXYGEN (O)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
6600	033242	051.1040	003397
6700	033746	051.1798	001783
6800	034249	051.2547	000168
6900	034758	051.3290	-001445
7000	035267	051.4023	-003060
7100	035776	051.4745	-004675
7200	036285	051.5457	-006291
7300	036794	051.6160	-007906
7400	037304	051.6852	-009522
7500	037813	051.7536	-011137
7600	038322	051.8210	-012753
7700	038831	051.8881	-014369
7800	039346	051.9545	-015985
7900	039861	052.0201	-017601
8000	040376	052.0849	-019218
8100	040891	052.1488	-020835
8200	041406	052.2120	-022451
8300	041920	052.2744	-024068
8400	042435	052.3361	-025686
8500	042950	052.3971	-027303
8600	043465	052.4577	-028920
8700	043986	052.5179	-030538
8800	044507	052.5774	-032156
8900	045028	052.6363	-033774
9000	045549	052.6945	-035391
9100	046070	052.7521	-037010
9200	046591	052.8090	-038628
9300	047112	052.8654	-040246
9400	047633	052.9211	-041865
9500	048154	052.9762	-043484
9600	048675	053.0308	-045102
9700	049196	053.0848	-046721
9800	049717	053.1382	-048340
9900	050238	053.1911	-049960

TABLE XVI

MOLECULAR OXYGEN (O_2)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
100	000690	037.3131	0
150	001038	040.1343	0
200	001386	042.1360	0
250	001734	043.6886	0
300	002068	044.9248	0
350	002419	046.0072	0
400	002770	046.9448	0
450	003121	047.7718	0
500	003472	048.5116	0
537	003732	049.0128	0
600	004174	049.7918	0
700	004888	050.8961	0
800	005608	051.8570	0
900	006347	052.7293	0
1000	007091	053.5123	0
1100	007844	054.2337	0
1200	008632	054.9197	0
1300	009421	055.5507	0
1400	010209	056.1349	0
1500	010997	056.6789	0
1600	011826	057.2180	0
1700	012660	057.7234	0
1800	013493	058.1999	0
1900	014327	058.6506	0
2000	015164	059.0811	0
2100	016017	059.4971	0
2200	016870	059.8938	0
2300	017722	060.2729	0
2400	018575	060.6358	0
2500	019442	060.9916	0
2600	020316	061.3344	0
2700	021190	061.6642	0
2800	022064	061.9820	0
2900	022938	062.2886	0
3000	023811	062.5849	0

TABLE XVI

MOLECULAR OXYGEN (O_2)

T °R	H°-H°$_f$	S°	ΔF°_f
3100	024685	062.8714	0
3200	025571	063.1550	0
3300	026473	063.4329	0
3400	027376	063.7024	0
3500	028279	063.9641	0
3600	029182	064.2185	0
3700	030085	064.4659	0
3800	030988	064.7067	0
3900	031891	064.9412	0
4000	032794	065.1698	0
4100	033706	065.3970	0
4200	034636	065.6212	0
4300	035566	065.8401	0
4400	036496	066.0539	0
4500	037427	066.2629	0
4600	038357	066.4674	0
4700	039287	066.6674	0
4800	040217	066.8633	0
4900	041147	067.0550	0
5000	042087	067.2462	0
5100	043042	067.4354	0
5200	043997	067.6208	0
5300	044952	067.8027	0
5400	045907	067.9813	0
5500	046862	068.1565	0
5600	047817	068.3286	0
5700	048772	068.4977	0
5800	049727	068.6638	0
5900	050690	068.8295	0
6000	051666	068.9936	0
6100	052643	069.1549	0
6200	053619	069.3137	0
6300	054595	069.4699	0
6400	055571	069.6236	0
6500	056547	069.7750	0

TABLE XVI

MOLECULAR OXYGEN (O_2)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
6600	057524	069.9240	0
6700	058500	070.0708	0
6800	059482	070.2171	0
6900	060475	070.3621	0
7000	061468	070.5050	0
7100	062461	070.6459	0
7200	063454	070.7840	0
7300	064448	070.9210	0
7400	065441	071.0569	0
7500	066434	071.1902	0
7600	067427	071.3218	0
7700	068424	071.4532	0
7800	069430	071.5830	0
7900	070436	071.7112	0
8000	071443	071.8378	0
8100	072449	071.9628	0
8200	073455	072.0863	0
8300	074461	072.2083	0
8400	075468	072.3288	0
8500	076474	072.4479	0
8600	077481	072.5664	0
8700	078497	072.6838	0
8800	079513	072.7999	0
8900	080528	072.9147	0
9000	081544	073.0282	0
9100	082560	073.1404	0
9200	083575	073.2514	0
9300	084591	073.3612	0
9400	085606	073.4698	0
9500	086622	073.5773	0
9600	087638	073.6836	0
9700	088653	073.7889	0
9800	089669	073.8931	0
9900	090685	073.9962	0

TABLE XVII

HYDROXYL (OH)

T °R	$H^\circ - H^\circ_0$	S°	ΔF°_f
100	000696	038.6963	016940
150	001054	041.6043	016458
200	001413	043.6676	015959
250	001772	045.2680	015447
300	002096	039.7303	016957
350	002453	040.8311	016773
400	002810	041.7847	016587
450	003167	042.6258	016401
500	003524	043.3781	016213
537	003788	043.8879	016073
600	004238	044.6801	015835
700	003652	045.7787	014158
800	004359	046.7233	013778
900	006358	047.5530	014694
1000	007063	048.2956	014316
1100	007764	048.9645	013943
1200	008473	049.5812	013570
1300	009182	050.1484	013201
1400	009890	050.6736	012834
1500	010599	051.1626	012470
1600	011315	051.6273	012109
1700	012049	052.0718	011751
1800	012782	052.4909	011396
1900	013515	052.8874	011043
2000	014249	053.2659	010691
2100	015004	053.6344	010343
2200	015759	053.9857	009997
2300	016514	054.3213	009652
2400	017269	054.6427	009310
2500	018049	054.9619	008971
2600	018836	055.2708	008632
2700	019624	055.5680	008293
2800	020411	055.8544	007957
2900	021199	056.1307	007621
3000	021986	056.3977	007287

TABLE XVII

HYDROXYL (OH)

T °R	H° -H$_0^\circ$	S°	ΔF_f°
3100	022774	056.6559	006953
3200	023587	056.9154	006624
3300	024417	057.1711	006293
3400	025248	057.4191	005963
3500	026079	057.6599	005634
3600	026910	057.8939	005305
3700	027741	058.1216	004978
3800	028571	058.3431	004651
3900	029402	058.5589	004325
4000	030233	058.7693	003999
4100	031078	058.9790	003678
4200	031939	059.1866	003354
4300	032801	059.3893	003032
4400	033662	059.5873	002709
4500	034523	059.7809	002388
4600	035385	059.9702	002067
4700	036246	060.1555	001747
4800	037108	060.3368	001428
4900	037969	060.5144	001109
5000	038843	060.6938	000782
5100	039726	060.8689	000465
5200	040610	061.0405	000148
5300	041494	061.2088	-000167
5400	042378	061.3740	-000482
5500	043262	061.5362	-000797
5600	044145	061.6954	-001111
5700	045029	061.8519	-001424
5800	045913	062.0056	-001737
5900	046804	062.1596	-002049
6000	047706	062.3111	-002360
6100	048607	062.4601	-002671
6200	049509	062.6067	-002981
6300	050410	062.7510	-003290
6400	051312	062.8929	-003599
6500	052213	063.0327	-003907

TABLE XVII

HYDROXYL (OH)

T °R	$H^\circ - H^\circ_\circ$	S°	ΔF°_f
6600	053115	063.1703	-004214
6700	054016	063.3059	-004521
6800	054933	063.6102	-005968
6900	055849	063.7439	-006291
7000	056765	063.8757	-006612
7100	057682	064.0057	-006933
7200	058598	064.1338	-007253
7300	059514	064.2602	-007573
7400	060430	064.3849	-007892
7500	061346	064.5079	-008210
7600	062263	064.6292	-008528
7700	063210	064.5865	-007553
7800	064139	064.7063	-007853
7900	065068	064.8247	-008153
8000	065997	064.9415	-008451
8100	066926	065.0569	-008749
8200	067855	065.1709	-009047
8300	068784	065.2835	-009343
8400	069713	065.3948	-009639
8500	070642	065.5047	-009935
8600	071626	065.6203	-010226
8700	072566	065.7291	-010521
8800	073507	065.8366	-010815
8900	074447	065.9429	-011108
9000	075388	066.0479	-011401
9100	076329	066.1519	-011694
9200	077269	066.2547	-011985
9300	078210	066.3564	-012276
9400	079150	066.4570	-012567
9500	080091	066.5565	-012857
9600	081032	066.6550	-013146
9700	081972	066.7525	-013435
9800	082913	066.8489	-013723
9900	083853	066.9444	-014011

TABLE XVIII

EQUILIBRIUM CONSTANTS

T °R	$CO_2 = CO + 1/2\ O_2$ K_p	$CO_2 + H_2 = CO + H_2O$ K_p	$H_2 + 1/2\ O_2 = H_2O$ K_p
2000	00.	1.048793	
2100	00.000000	01.245660	
2200	00.000000	01.452540	
2300	00.000000	01.668424	
2400	00.000000	01.890014	
2500	00.000000	02.112691	
2600	00.000002	02.341048	
2700	00.000004	02.570713	
2800	00.000010	02.800329	
2900	00.000022	03.028711	
3000	00.000045	03.254834	
3100	00.000087	03.477819	
3200	00.000161	03.702288	
3300	00.000286	03.917987	
3400	00.000490	04.129232	
3500	00.000813	04.335633	
3600	00.001311	04.536873	
3700	00.002059	04.732706	
3800	00.003157	04.922953	
3900	00.004733	05.107483	
4000	00.006950	05.286217	
4100	00.010005	05.455289	
4200	00.014161	05.622648	
4300	00.019715	05.784433	
4400	00.027029	05.940690	
4500	00.036527	06.091477	
4600	00.048707	06.236874	
4700	00.064140	06.376972	99.422421
4800	00.083476	06.511869	78.008835
4900	00.107450	06.641678	61.811675
5000	00.136921	06.771100	49.452330

TABLE XVIII

EQUILIBRIUM CONSTANTS

T °R	$CO_2=CO+1/2\ O_2$ K_p	$CO_2+H_2=CO+H_2O$ K_p	$H_2+1/2\ O_2=H_2O$ K_p
5100	00.172741	06.891359	39.894068
5200	00.215943	07.006969	32.448189
5300	00.267626	07.118055	26.596954
5400	00.328984	07.224738	21.960706
5500	00.401304	07.327154	18.258349
5600	00.485964	07.425429	15.279774
5700	00.584434	07.519682	12.866589
5800	00.698272	07.610048	10.898389
5900	00.829273	07.671835	09.251275
6000	00.978886	07.754605	07.921860
6100	01.149042	07.833842	06.817712
6200	01.341613	07.909662	05.895633
6300	01.558538	07.982174	05.121578
6400	01.801815	08.051498	04.468547
6500	02.073500	08.117741	03.914994
6600	02.375692	08.181005	03.443629
6700	02.710535	08.241397	03.040504
6800	03.077474	08.317030	02.702550
6900	03.483833	08.372048	02.403114
7000	03.929431	08.424441	02.143933
7100	04.416514	08.474305	01.918776
7200	04.947333	08.521723	01.722488
7300	05.524142	08.566787	01.550790
7400	06.149191	08.609583	01.400116
7500	06.824721	08.650189	01.267478
7600	07.552957	08.688687	01.150368
7700	08.339230	08.711431	01.044632
7800	09.179794	08.745867	00.952730
7900	10.079620	08.778356	00.870901
8000	11.040814	08.808971	00.797855

TABLE XVIII

EQUILIBRIUM CONSTANTS

	$CO_2=CO+1/2\ O_2$	$CO_2+H_2=CO+H_2O$	$H_2+1/2\ O_2=H_2O$
T °R	K_p	K_p	K_p
8100	12.065450	08.837780	00.732486
8200	13.155544	08.864848	00.673848
8300	14.313070	08.890241	00.621127
8400	15.539944	08.914017	00.573619
8500	16.838034	08.936239	00.530717
8600	18.204395	08.966896	00.492567
8700	19.649878	08.986123	00.457311
8800	21.171767	09.003894	00.425278
8900	22.771664	09.020269	00.396118
9000	24.451119	09.035298	00.369524
9100	26.211592	09.049030	00.345230
9200	28.054470	09.061513	00.322997
9300	29.981093	09.072794	00.302617
9400	31.992701	09.082918	00.283905
9500	34.090462	09.091925	00.266699
9600	36.275494	09.099858	00.250854
9700	38.548811	09.106760	00.236239
9800	40.911361	09.112665	00.222741
9900	43.364034	09.117612	00.210257

TABLE XIX

EQUILIBRIUM CONSTANTS

T °R	$H_2O=OH+1/2\ H_2$ K_p	$H_2=2H$ K_p	$O_2=2O$ K_p
2000			
2100	00		
2200	00		
2300	00		
2400	00		
2500	00		
2600	00		
2700	00		
2800	00		
2900	00.000002	00.00	
3000	00.000004	00.00	
3100	00.000008	00.00	
3200	00.000015	00.00	
3300	00.000027	00.00	
3400	00.000049	00.00	
3500	00.000083	00.000001	00.000000
3600	00.000137	00.000002	00.000000
3700	00.000221	00.000005	00.000001
3800	00.000346	00.000011	00.000002
3900	00.000530	00.000021	00.000005
4000	00.000794	00.000040	00.000011
4100	00.001167	00.000074	00.000022
4200	00.001685	00.000131	00.000042
4300	00.002390	00.000226	00.000077
4400	00.003337	00.000382	00.000138
4500	00.004590	00.000630	00.000242
4600	00.006228	00.001016	00.000412
4700	00.008341	00.001606	00.000687
4800	00.011036	00.002492	00.001120
4900	00.014435	00.003799	00.001790
5000	00.018689	00.005698	00.002808

TABLE XIX

EQUILIBRIUM CONSTANTS

	$H_2O=OH+1/2\ H_2$	$H_2=2H$	$O_2=2O$
T °R	K_p	K_p	K_p
5100	00.023941	00.008410	00.004329
5200	00.030378	00.012231	00.006563
5300	00.038200	00.017542	00.009797
5400	00.047631	00.024831	00.014409
5500	00.058915	00.034712	00.020899
5600	00.072320	00.047956	00.029914
5700	00.088139	00.065519	00.042286
5800	00.106687	00.088569	00.059069
5900	00.128740	00.118460	00.081592
6000	00.153875	00.157017	00.111495
6100	00.182843	00.206233	00.150814
6200	00.216057	00.268533	00.202028
6300	00.253955	00.346771	00.268145
6400	00.296995	00.444285	00.352778
6500	00.345659	00.564953	00.460241
6600	00.400450	00.713250	00.595643
6700	00.461890	00.894314	00.764996
6800	00.575521	01.114188	00.975314
6900	00.658396	01.379170	01.234776
7000	00.750316	01.696902	01.552803
7100	00.851924	02.075799	01.940225
7200	00.963884	02.525272	02.409413
7300	01.086874	03.055790	02.974432
7400	01.221583	03.678955	03.651187
7500	01.368715	04.407575	04.457588
7600	01.528983	05.255724	05.413706
7700	01.568327	06.238398	06.541537
7800	01.742151	07.373044	07.866679
7900	01.930104	08.677544	09.416366
8000	02.132871	10.171645	11.220985

TABLE XIX

EQUILIBRIUM CONSTANTS

	$H_2O=OH+1/2\ H_2$	$H_2=2H$	$O_2=2O$
T °R	K_p	K_p	K_p
8100	02.351140	11.876682	13.313938
8200	02.585602	13.815611	15.731794
8300	02.836946	16.013073	18.514464
8400	03.105865	18.495460	21.705379
8500	03.393045	21.290933	25.351639
8600	03.693260	24.420765	29.505229
8700	04.018603	27.932562	34.219115
8800	04.364385	31.852341	39.553339
8900	04.731097	36.215577	45.571251
9000	05.119472	41.059703	52.340664
9100	05.530167	46.424038	59.933911
9200	05.963833	52.349842	68.427992
9300	06.421115	58.880416	77.904751
9400	06.902541	66.060945	88.450391
9500	07.409035	73.938544	00.158079
9600	07.940907	82.562428	13.123181
9700	08.498851	91.983596	27.448105
9800	09.083451	102.255080	43.240017
9900	09.695281	113.431833	60.611465

TABLE XX

EQUILIBRIUM CONSTANTS

T °R	$1/2\ N_2 = N$ K_p	$1/2\ N_2 + 1/2\ O_2 = NO$ K_p	$1/2\ B_2O_3 = BO + 1/4\ O_2$ K_p
2000	0	0 0 0 0 0 254	0 0 . 0 0 0 0 0 0
2100	0 0 .	405	0 0 . 0 0 0 0 0 0
2200	0 0 .	620	0 0 . 0 0 0 0 0 0
2300	0 0 .	913	0 0 . 0 0 0 0 0 0
2400	0 0 .	1303	0 0 . 0 0 0 0 0 0
2500	0 0 .	1792	0 0 . 0 0 0 0 0 0
2600	0 0 .	2423	0 0 . 0 0 0 0 0 0
2700	0 0 .	3204	0 0 . 0 0 0 0 0 0
2800	0 0 .	4153	0 0 . 0 0 0 0 0 0
2900	0 0 .	5288	0 0 . 0 0 0 0 0 0
3000	0	6626	0 0 . 0 0 0 0 0 0
3100	0 0 .	8182	0 0 . 0 0 0 0 0 0
3200	0 0 .	10040	0 0 . 0 0 0 0 0 0
3300	0 0 .	12090	0 0 . 0 0 0 0 0 0
3400	0 0 .	14400	0 0 . 0 0 0 0 0 0
3500	0 0 .	16981	0 0 . 0 0 0 0 0 0
3600	0 0 .	19840	0 0 . 0 0 0 0 0 0
3700	0 0 . 0 0 0 0 0 1	0 0 . 0 2 2 9 8 7	0 0 . 0 0 0 0 0 0
3800	0 0 . 0 0 0 0 0 2	0 0 . 0 2 6 4 2 8	0 0 . 0 0 0 0 0 0
3900	0 0 . 0 0 0 0 0 4	0 0 . 0 3 0 1 6 6	0 0 . 0 0 0 0 0 0
4000	0 0 . 0 0 0 0 0 7	0 0 . 0 3 4 2 0 5	0 0 . 0 0 0 0 0 0
4100	0 0 . 0 0 0 0 1 2	0 0 . 0 3 8 5 5 9	0 0 . 0 0 0 0 0 0
4200	0 0 . 0 0 0 0 2 0	0 0 . 0 4 3 2 0 6	0 0 . 0 0 0 0 0 0
4300	0 0 . 0 0 0 0 3 1	0 0 . 0 4 8 1 5 7	0 0 . 0 0 0 0 0 0
4400	0 0 . 0 0 0 0 4 8	0 0 . 0 5 3 4 0 8	0 0 . 0 0 0 0 0 0
4500	0 0 . 0 0 0 0 7 2	0 0 . 0 5 8 9 5 9	0 0 . 0 0 0 0 0 0
4600	0 0 . 0 0 0 1 0 6	0 0 . 0 6 4 8 0 4	0 0 . 0 0 0 0 0 1
4700	0 0 . 0 0 0 1 5 3	0 0 . 0 7 0 9 4 2	0 0 . 0 0 0 0 0 2
4800	0 0 . 0 0 0 2 1 8	0 0 . 0 7 7 3 6 6	0 0 . 0 0 0 0 0 4
4900	0 0 . 0 0 0 3 0 5	0 0 . 0 8 4 0 7 1	0 0 . 0 0 0 0 0 7
5000	0 0 . 0 0 0 4 2 2	0 0 . 0 9 1 0 7 6	0 0 . 0 0 0 0 1 3

TABLE XX

EQUILIBRIUM CONSTANTS

	$1/2\ N_2 = N$	$1/2\ N_2 + 1/2\ O_2 = NO$	$1/2\ B_2O_3 = BO + 1/4\ O_2$
T °R	K_p	K_p	K_p
5100	00.000577	00.098328	00.000021
5200	00.000779	00.105840	00.000035
5300	00.001040	00.113606	00.000057
5400	00.001374	00.121617	00.000089
5500	00.001797	00.129867	00.000138
5600	00.002328	00.138346	00.000211
5700	00.002988	00.147047	00.000317
5800	00.003803	00.155961	00.000470
5900	00.004802	00.165217	00.000721
6000	00.006016	00.174537	00.001038
6100	00.007482	00.184045	00.001476
6200	00.009241	00.193731	00.002075
6300	00.011339	00.203587	00.002886
6400	00.013825	00.213605	00.003971
6500	00.016755	00.223778	00.005410
6600	00.020189	00.234096	00.007301
6700	00.024194	00.244553	00.009763
6800	00.028843	00.254955	00.012600
6900	00.034212	00.265659	00.016584
7000	00.040385	00.276476	00.021655
7100	00.047453	00.287401	00.028062
7200	00.055512	00.298426	00.036098
7300	00.064667	00.309544	00.046111
7400	00.075027	00.320749	00.058506
7500	00.086707	00.332033	00.073755
7600	00.099831	00.343392	00.092403
7700	00.114539	00.354302	00.112328
7800	00.130949	00.365779	00.139090
7900	00.149215	00.377312	00.171281
8000	00.169487	00.388894	00.209809

TABLE XX

EQUILIBRIUM CONSTANTS

	$1/2\ N_2 = N$	$1/2\ N_2 + 1/2\ O_2 = NO$	$1/2\ B_2O_3 = BO + 1/4\ O_2$
T °R	K_p	K_p	K_p
8100	00.191921	00.400521	00.255695
8200	00.216681	00.412188	00.310090
8300	00.243938	00.423868	00.374279
8400	00.273866	00.435619	00.449698
8500	00.306650	00.447374	00.537941
8600	00.342511	00.457704	00.656406
8700	00.381584	00.469479	00.778708
8800	00.424103	00.481267	00.920148
8900	00.470274	00.493063	01.083131
9000	00.520311	00.504864	01.270281
9100	00.574432	00.516666	01.484455
9200	00.632860	00.528466	01.728758
9300	00.695825	00.540260	02.006549
9400	00.763560	00.552045	02.321455
9500	00.836302	00.563818	02.677383
9600	00.914294	00.575576	03.078529
9700	00.997781	00.587317	03.529388
9800	01.087014	00.599038	04.034767
9900	01.182246	00.610736	04.599791

TABLE XXI

EQUILIBRIUM CONSTANTS

	$B+1/2\ O_2=BO$	$CO=1/2\ C_s+1/2\ CO_2$
T °R	K_p	K_p
2000	00.022110	00.227626
2100	00.018802	00.147148
2200	00.016211	00.099110
2300	00.014145	00.069175
2400	00.012473	00.049809
2500	00.011220	00.044199
2600	00.010068	00.033513
2700	00.009102	00.025964
2800	00.008284	00.020505
2900	00.007585	00.016474
3000	00.006982	00.013442
3100	00.006459	00.011121
3200	00.006001	00.009316
3300	00.005599	00.007895
3400	00.005244	00.006761
3500	00.004929	00.005846
3600	00.004647	00.005099
3700	00.004394	00.004483
3800	00.004166	00.003970
3900	00.003959	00.003540
4000	00.003772	00.003176
4100	00.003600	00.002868
4200	00.003444	00.002602
4300	00.003300	00.002373
4400	00.003169	00.002174
4500	00.003047	00.002000
4600	00.002934	00.001847
4700	00.002830	00.001713
4800	00.002733	00.001594
4900	00.002643	00.001488
5000	00.002537	00.001393

TABLE XXI

EQUILIBRIUM CONSTANTS

	$B+1/2\ O_2=BO$	$CO=1/2\ C_s+1/2\ CO_2$
T °R	K_p	K_p
5100	00.002458	00.001309
5200	00.002384	00.001233
5300	00.002315	00.001164
5400	00.002250	00.001102
5500	00.002189	00.001045
5600	00.002132	00.000994
5700	00.002077	00.000947
5800	00.002026	00.000903
5900	00.002130	00.000864
6000	00.002077	00.000828
6100	00.002027	00.000794
6200	00.001980	00.000763
6300	00.001934	00.000735
6400	00.001891	00.000708
6500	00.001851	00.000684
6600	00.001812	00.000661
6700	00.001774	00.000639
6800	00.001649	00.000620
6900	00.001619	00.000601
7000	00.001589	00.000584
7100	00.001562	00.000567
7200	00.001535	00.000552
7300	00.001509	00.000537
7400	00.001484	00.000524
7500	00.001460	00.000511
7600	00.001438	00.000499
7700	00.001404	00.000491
7800	00.001383	00.000480
7900	00.001363	00.000470
8000	00.001343	00.000460

TABLE XXI

EQUILIBRIUM CONSTANTS

	$B+1/2\ O_2=BO$	$CO=1/2\ C_s+1/2\ CO_2$
T °R	K_p	K_p
8100	00.001324	00.000451
8200	00.001306	00.000442
8300	00.001288	00.000434
8400	00.001271	00.000426
8500	00.001254	00.000418
8600	00.001249	00.000410
8700	00.001233	00.000403
8800	00.001218	00.000397
8900	00.001203	00.000390
9000	00.001189	00.000384
9100	00.001175	00.000379
9200	00.001161	00.000373
9300	00.001148	00.000368
9400	00.001135	00.000363
9500	00.001123	00.000358
9600	00.001111	00.000353
9700	00.001099	00.000349
9800	00.001087	00.000345
9900	00.001076	00.000340

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